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CHINESE SPACE EXPLORATION

Zhu Yilin

Translation of "Zhong Guo De Kong Jian Tan Ce"; Aerospace China, No.11, Nov 1993, pp 4-6

Astronavigational activities can be roughly divided into the three areas of satellite applications, manned astronavigation, and space exploration.

China is a developing nation. At the present time, its economic strength is not abundant. In the area of astronavigational activities, it is only capable of making limited investments. As a result, China's development of astronavigational activities must comply with the guidance, "Limited objectives. Stress on key points. Urgent needs have priority." At a minimum, before the year 2000, the main mission of China's astronavigational activities is the development of applied satellites having significant, direct effects with regard to the national economy, national defense construction, and social progress--for example, such satellites as communications broadcasting, metrological survey, natural resources prospecting, reconnaissance survey of national territory, disaster monitoring, navigation and positioning, and so on.

In the areas of the exploration and survey of outer space, it is only possible to make appropriate arrangements. Up to the present time, China has only carried out several iterations of probes in near earth space.

China's space probe activities began with the T-7 sounding rockets of the early 1960's. Making use of the rockets in question, preliminary measurements were carried out with regard to the upper layers of the atmosphere in ranges of 60 to over 100km, acquiring a number of useful data.

SPACE SURVEY SATELLITES

The first satellite used in space surveying was the second man made Chinese satellite, launched 22 years ago--the Practical Realization No.1 satellite. On 3 March 1971, the Practical Realization No.1 satellite was launched by a Long March No.1 carrier rocket. It entered into an orbit with a perigee altitude of 266 kilometers and an apogee altitude of 1826 kilometers. Angle of inclination was 69.9 degrees. The satellite in question operated for 8 years in space. In the first instance, it surveyed such space environmental data as magnetic fields, solar X rays, cosmic rays, as well as space heat flows, and so on, in near earth space.

On 20 September, 1981, China used a Windstorm No.1 carrier rocket and simultaneously launched three space survey satellites.

They entered into orbits with perigee altitudes of 237 kilometers and apogee altitudes of 1622 kilometers. Angle of inclination was 60 degrees. The main Practical Realization No.2 satellite among the "one rocket three satellites" was a space survey and scientific experiment satellite. The weight was 250kg. Carried on board the satellite were 11 types of instruments. Among them, magnetometers, semiconductor proton direction detectors, semiconductor proton semi-omnidirectional detectors, semiconductor electron direction detectors, as well as scintillation counters were used in measuring protons, electrons, and geomagnetic fields associated with near earth space. Long and short wave infrared radiometers and earth-atmosphere ultraviolet radiometers were used in measuring earth and atmospheric infrared and ultraviolet radiation backgrounds. Solar intermediate ultraviolet radiometers and solar X ray detectors were used in monitoring solar activities. Thermoionic gas pressure meters were used in measuring high altitude atmospheric densities, and so on.

The Practical Realization No.2 satellite only operated in orbit a short time. It developed malfunctions and stopped operating. However, it still sent back large amounts of valuable space physics data.

The second satellite among the three was the Practical Realization No.2 A satellite. It went through electric waves of two types of frequencies transmited toward the surface at 40.5MHz and 162MHz. They penetrated through the ionosphere and arrived at the surface. After surface station reception, use was made of Faraday effects and two types of Doppler frequency methods to acquire such data as ionosphere electron concentrations, supplying precious source material for studying electric wave propogation associated with the ionosphere.

On 3 March 1990, at the same time as the launch of the Wind and Clouds No.1 metrological satellite, two balloon satellites--the Atmosphere No.1 and the Atmosphere No.2--were piggy back launched on a Long March No.4 carrier rocket. The diameter of the two satellites was 3 meters in both cases. The outer surface was covered with a shiny plated aluminum film, facilitating surface tracking observations. Through observation and analysis of changes associated with satellite orbit parameters, surface tracking stations calculated out atmospheric density data associated with altitude ranges of 400-900 kilometers.

Besides this, on all previously launched returnable model remote sensing satellites, communications satellites, and metrological satellites, different space survey instruments were piggy backed one after the other. For example, on the East Is Red No.2 and the East Is Red No.2 A satellites, semiconductor electron detectors, semiconductor proton detectors, as well as solar X ray detectors, and so on, were piggy backed in succession--used in measuring electron and proton strength variations in geosynchronous orbits, solar X ray strength spectra, and static electric potential associated with monitoring satellite surfaces, thereby supplying data in order to empirically verify solar activity predictions.

At the present time, China is just in the midst of making use of mature technology which was mastered during the development of satellites in the past as well as components which have gone through space testing to develop small model, low cost Practical Realization No.4 space survey satellites in order to facilitate the large scale shortening of satellite development cycles, lowering space survey costs. Practical Realization No.4 satellites will carry 6 types of instruments used in measuring the influences of high energy electrons and protons, plasma, satellite surface electrical potentials, as well as high energy particles in geosynchronous transfer orbits with regard to satellite components. Practical Realization No.4 satellites will act as distribution weight useful loads to carry out flight tests of the new carrier rocket Long March No.3 A, to be launched in 1993 or somewhat later.

1990'S SPACE SURVEY PLAN /5

At the end of the 1980's, Chinese space scientists--with a view toward the 1990-92 22d solar activity peak years as well as the 2001-2004 23d solar activity peak years--put forward proposals for a near earth space survey ten year plan. The proposal in question takes space survey activities before the year 2000 and divides them into three stages.

The first phase (1990-1993) is the preparation phase.

Within this phase, survey plans will be put forward. Necessary survey instruments will be developed. Preparations are made for survey activities associated with second phase valley years of solar activity. Foreign environmental models are collected and introduced. Research and analysis are carried out to act as a basis for contrast. Preparations are made for construction of surface simulations of real space environments as well as controlable magnetic field laboratories. Development is done of research associated with the interactions of space environments with spacecraft. Studies are done of digital simulation methods, introducing and developing calculations of software associated with effects of various types of space environments on spacecraft. Development is done of research associated with space environment forecasting methods--setting up, step by step, Chinese forecasting models. Surface observation networks are gradually improved, and so on.

The second phase (1994-1997) is the implementation phase.

Within this phase, use will be made of sounding rockets and artificial satellites to carry out space environment surveys, acquiring data. In conjunction with this, analysis is completed with regard to the data obtained. With a view to the requirements of relevent spacecraft designs, development is done of digital simulation work associated with interactions of space environments and spacecraft. Comprehensive development work is done on laboratory simulation work associated with interactions. Improvement of surface obseration networks is continued. On the basis of domestic monitoring data and forecast models, supplementary forecasts are made with regard to foreign predictions, in conjuction with this, improving forecast models.

The third phase (1998-2000).

In this phase, use will be made of comparisions of China's own experimentally measured data and foreign models, correcting the foreign models. Construction will be completed on surface observation networks. Prediction models will be completed using domestic monitoring data as their foundation, possessing independent forecasting capabilities, and participating in international space environment forecasting work. A new generation of survey instruments will be developed, making preparations for the carrying out of space surveys for the 23d

solar activity peak years 2001-2004.

THE EFFORTS OF YOUTH

In the area of deep space probes, China has still not yet set out plans relating to probes of the moon, Mars, and interplanetary space. However, Chinese space experts already have ideas relating to probes of the moon. A group of young Chinese scientific and technical personnel are enthusiastic about probes of interplanetary space. They have put forward in relatively concrete terms plans for lunar survey devices.

In 1989, ten or so young people associated with China's space technology research institute, the Chinese academy of sciences, and the Beijing aviation and astronavigation college organized a design team to participate in the "Columbus Space Sailing Cup" competition sponsored in association with the Columbus 500th anniversary commission.

They designed a plan for a lunar survey device using a windmill shaped solar sail for power. The take off weight of the survey device in question is approximately 500kg. The orbital weight is 420kg. The solar sail area is approximately 50 thousand square meters. The survey device in question carries a standard souvenir type useful load with a weight of 1kg and 24kg of survey instruments.

What is unfortunate is that, due to not having obtained funding support from the sponsors, one year later, the design team had no choice but to stop activities.

In 1992, a research team subordinate to China's space technology research academy--with the support of the science and technology committee of the academy in question--completed a preliminary feasibility study for a lunar survey device. They put forward a plan for a simple survey device to fly around the moon. Its primary missions are to survey lunar earth space and near lunar space environments--for example, lunar earth space and lunar magnetic fields, lunar gravitational fields, the earth's ionosphere and radiation belts, micrometeors, as well as cosmic dust, and so on.

As far as the design proposals of the team in question are concerned, one of the possible ways for launching the lunar survey device is to launch it piggy back on the newly developed Long March No.3 A carrier rocket in the same way as the Practical Realization No.4 satellite.

PROPOSALS RELATED TO MARS PROBES

Although China has still not set out a plan for probing deep space, Chinese space experts, however, are still very interested with regard to international cooperation associated with lunar exploitation and Mars probes. In conjunction with this, there is active participation in relevent international scholarly activities. On the occasion of the 1992 international space year, Chinese space experts put forward their own proposals associated with future Mars probe organizational agencies and legal questions. These suggestions gave rise to enormous interest among international colleagues. The proposals of Chinese experts were as follows.

1. It is best for the highest level organizational agency to be played by the United Nations outer space commission--unifying planning and arranging Mars survey activities associated with the various nations of the world. The outer space commission has already set up two scientific, technical, and legal subcommittees for space activities. It is possible, within these two subcommittees, to set up Mars probe working teams. After that, the United Nations General Assembly should pass a resolution relating to Mars probes in order to facilitate Mars probe activities obtaining the support of various member state governments. In conjunction with this, propoganda is carried out through various types of media, heightening interest among the broad masses.

2. In order to avoid the drawback of an enormous organization like the space commission not having enough flexibility to manage affairs and for the sake of beginning work as soon as possible, a semi-governmental organization similar to SAFISY (the international space year space agency forum) should be set up first--organized on a voluntary basis from such things as the astronavigational bureaus of various countries, scientific research units, and industrial departments. This organization's designation has been suggested as SAFIME (The Space Agency Forum on International Mars Exploration)--the international Mars survey space agency forum. At the present time, the astronavigational agencies of a number of countries are in the process of carrying out Mars planning that will become a good beginning for international cooperation and mutual aid.

3. Legal questions related to Mars surveys must be considered. However, due to this problem being very complicated, arriving at and signing a "Mars treaty" must be a process of negotiation and consultation which is long and drawn out. However, the signing of the 1959 "South Pole treaty" by 13 nations has already set a good precedent for us. In order to adapt to new situations, the 1979 "treaty relating to the guidance of various nations in activities on the moon and other celestial bodies" needs to go through discussion and consultation

for revisions. Before the "Mars treaty" takes shape, principles should first be set down to guide the Mars survey activities of different nations in order to facilitate the Mars survey activities of various nations as well as international cooperation that has references to abide by--not giving rise to contradications with currently existing international law.

4. In the area of funding required by activities, it is proposed to set up an international Mars exploration foundation. The sources of funding are:

- United Nations appropriations
- various Unitied Nations member state governments provide funding to the foundation in accordance with the proportion of United Nations expenses they pay
- contributions from nongovernmental agencies, groups, and private individuals
- appeals for relevent nations to take part of military expenses saved in arms reductions and use them in Mars probes

5. The survey and exploitation of Mars is a long term, joint activity of all of mankind. It should bring profit and benefit to the various nations of the world--no matter the size of tbe country or the level of development. The masses of the various countries and scientific groups should, in all cases, have the right to acquire information and data related to Mars survey activities.

Outer space and the earth are related to the fate of the human race and its prospects for joy or sorrow. Survey and exploitation includes the moon, Mars, and outer space with the other planets in it. Making this serve mankind is a joint objective and mission of the various nations of the whole world. Right along, China has been willing to carry out technical exchanges with scientists associated with the various nations of the world in line with a spirit of "spend what one can and do what one can"--developing bilateral or multilateral international cooperation. For surveys including the moon, Mars, and outer space with the other planets in it, we are making our own efforts and contributions.

PROGRESS IN CHINESE ASTRONAVIGATIONAL VISIBLE LIGHT PHOTOGRAPHIC SYSTEMS

Jiao Shijyu Li Dayao

Translation of "Wo Guo Hang Tian Ke Jian Guang She Ying Xi Tong De Jin Zhan"; Aerospace China, No.11, Nov.1993, pp 16-18

SYSTEM COMPONENTS AND OPERATING PRINCIPLES

Among various types of astronavigational remote sensing systems, visible light photographic systems are one type which was developed the earliest, fastest, and has the broadest application. They belong to optical photographic passive type imagery. By visible imagery remote sensing devices installed on spacecraft, target electromagnetic radiation information detected as well as differences in deep and light hues are directly recorded on light sensitive film or on electric charge coupler devices.

As far as methods by which remote sensing information is returned to the surface are concerned, they can be divided into returnable types and radio transmission types. With regard to returnable types, film is taken and first stored in recovery containers inside spacecraft. After astronavigational photographic missions are completed, the recovery containers in question are then returned from space to the surface. With respect to radio transmission types, imagery information which is acquired is first of all converted into electrical signals. Then, it is sent through radio to the ground stations or, going through data relay satellites, it is transmited to the surface. After surface stations receive signals, they take the electrical signals and convert them to the original images. Remote sensing

information which is sent back to the surface goes through interpretation by optical equipment, electronic computer processing, or interpreter personnel. Valuable data is extracted from it.

Fig.1 represents the entire technology system and operating processes applied in association with the collection, processing, and interpretation from remote sensing information associated with visible light photographic systems from the surface to space.

China has already successfully developed and, in conjunction with that, makes use of returnable forms of astronavigational visible light photographic systems. The space section is called a returnable type remote sensing satellite. Visible light cameras (remote sensing devices) are useful load associated with returnable type remote sensing satellites. They are also specialized subsystems of satellites.

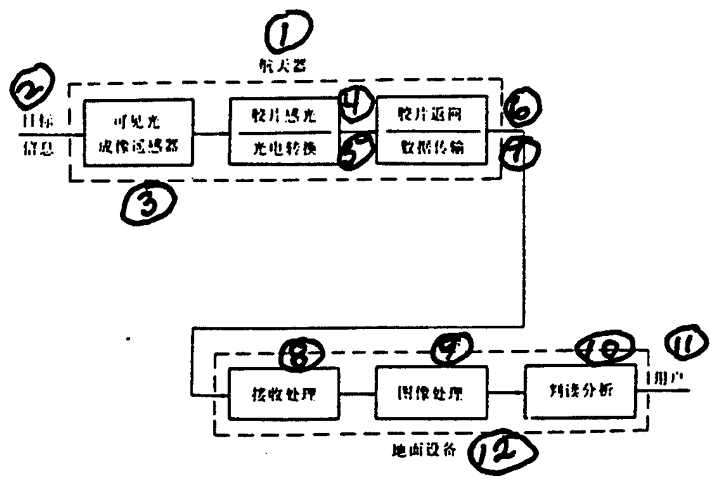


Fig.1 Astronavigational Visible Light Photographic System Schematic

Key: (1) Spacecraft (2) Target Information (3) Visible Light Imagery Remote Sensing Device (4) Film Sensing Light (5) Photoelectric Conversion (6) Film Return (7) Data Transmission (8) Reception Processing (9) Imagery Processing (10) Interpretation Analysis (11) User (12) Surface Equipment

Returnable type remote sensing satellites are a kind of satellite which has taken the lead in development among China's various types of applied satellites. Beginning in 1966, designs were demonstrated. In 1975, they were put into service. Up to 1992, there have already been 14 successive successful launches. Their returnable compartments all returned to the surface. The return success rate was 100%. This type of satellite operates in near earth quasi circular orbits. Overall mass is 1800-2600kg. Orbital operation time was 3-16 days. /17

Visible light camera subsystems associated with returnable type remote sensing satellites are a type of space remote sensing device which was developed earliest in China. The subsystems in question were composed of 1 surface feature camera unit, 1 star camera unit, as well as dark passages, film boxes, and so on. Among these, surface feature cameras were used in taking pictures of predesignated regions in orbit. Remote sensing information was collected in association with surface scenery. When surface feature cameras were operating, star cameras took pictures of the stars and space synchronously in order to correct satellite attitude errors after the fact. The film that was taken by these two camera units was sent through dark passages to the film boxes where it was sealed up and stored. After satellites complete predetermined photographic missions, the film boxes are loaded along with which the returnable compartments come back to the surface. After the exposed film is recovered on the surface, it goes through developing, and it is then possible to display target imagery. The remote sensing images obtained are true to life and clear. They are easy to interpret. Surface resolutions are comparatively high. Wide spread use is already made of them in various realms of the national economy. In conjunction with this, clear benefits have already been produced.

PROGRESS IN SURFACE FEATURE CAMERAS

Surface feature cameras in visible light camera subsystems associated with returnable type remote sensing satellites have undergone a process of development from prism scan type panoramic cameras and picture frame type measurement cameras to nodal point type panoramic cameras. The primary index acting to judge the performance superiority of this type of camera or its abscence was--have surface resolutions associated with photographs taken in the same orbit at the same altitude already reached the levels of foreign cameras of the same type.

Prism scanning type panoramic cameras possess such advantages as large photographic coverage areas, compact structures, and so on. The front surface of the lens of this type of camera has two prisms. The axis of rotation of the prisms and the direction of flight are parallel. When taking photos, scanning is carried out of surface features through prism rotation. As far as light coming from surface objects is concerned, after it enters into lenses through prisms, it goes through a slit in front of the film, making the film register light and form images. In order to achieve clear imagery, it is necessary to guarantee that, when pictures are taken, surface object imagery displacement speeds due to prism rotation and film movement speeds are the same. This type of speed synchronicity precision is one of the prime factors influencing the quality of the photographs. Besides this, prisms will make camera relative apertures shrink. In conjunction with this, double images are produced. Therefore, as far as this type of camera is concerned, although the relative difficulty of its development is comparatively small, its photographic quality, however, does not compare to other panaoramic cameras possessing the same optical parameters.

When picture frame type survey measurement cameras take photos, the direction of optical axis pointing is invariable. Making use of opening and closing the shutter, target photographs within the visual field of the lens are focused on the light sensitive film. It is possible to supply imagery with wide angle fields of view. The geometrical relationships associated with the imagery are relatively rigorous. They are normally used in map making. As far as this type of astronavigational picture frame type survey measurement camera which China has developed is concerned, the focal length and frame area can be favorablly compared to large frame cameras on the U.S. space shuttle and survey cameras in the European space agency's space laboratory. The technical indices are also quite close to the space laboratory's survey measurement cameras. As far as the development of this type of survey measurement camera--with wide field of view, low distortion, high geometrical precision, high spacial resolution, and satisfying conditions associated with satellite structural constraints--is concerned, it is necessary to resolve such relevent technical problems as large field of view optical system design, high speed center type shutters, high power and high stability focusing tube development, directional element measurements within high precisions, film roller structures, film presentation structures, image movement compensation structures, and so on.

Nodal point type panoramic cameras eliminate scanning prisms, avoiding speed synchronicity difficulties and improving surface resolutions to a large extent. They are fixed like prism scanning type panoramic scanning lenses. Only the rotating prisms are different. Entire focusing tubes associated with nodal point type panoramic cameras are scanning perpendicular to

the direction of flight. As a result, the structural dimensions are comparatively large. Development of this type of camera requires the resolution of such key technical problems as focusing tube assembly and adjustment, precise determinations of nodal point positions, and so on. Surface resolutions associated with astronavigational nodal point type panoramic cameras developed in China are better than the surface resolutions associated with prism scanning type panoramic cameras. This means that photographs using nodal point type panoramic cameras are also able to reflect targets with relatively small surface dimensions on film. As a result, it is clearly shown that successful development of nodal point type panoramic cameras makes China's astronavigational visible light remote sensing devices jump up to a new stage.

PROGRESS IN STAR CAMERAS

The subjects which surface feature cameras must photograph--objects on the earth and in its atmosphere (earth-atmosphere system)--are only a few hundred kilometers apart and reflectances are also very strong (the greatest degree of solar irradiation on the surface of the earth is approximately 1.3x105 lux. In accordance with a mean earth-atmosphere system albedo calculated as 0.33, earth-atmosphere system reflectances can reach 4.3x104 lux). However, the targets which star cameras must photograph--fixed stars--are, by contrast, extremely weak point light sources infinitely far away.

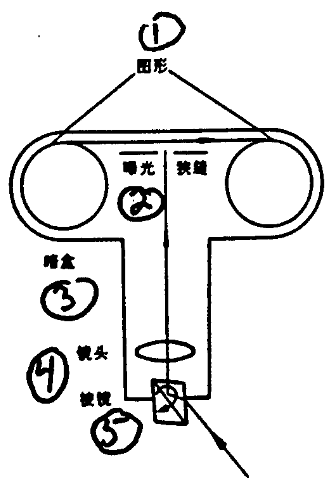


Fig.2 Diagram of the Operating Principles of Prism Scan Type Panoramic Cameras

Key: (1) Winding Forms (Illegible) (2) Light Exposure Slit (Illegible) (3) Magazine Cassette (4) Lens (5) Prism

The brightness of stars is represented by star magnitudes. It is judged by means of the intensity of star illumination received in the atmosphere. The ratio of illuminances associated with two adjacent stellar magnitudes is 1001/5. The higher the stellar magnitude, the smaller the intensity of illumination. The dimmest star the human eye is capable of seeing is a magnitude 6 star. The intensity of illumination is only 1x10-8 lux. The brightest magnitude star the human eye is capable of seeing has an average value approximately equal to 1. The corresponding intensity of illumination has only 1x10-6 lux. The threshold value stars which satellite borne star cameras strive to photograph are greater than or equal to 5. The intensity of illumination is very small.

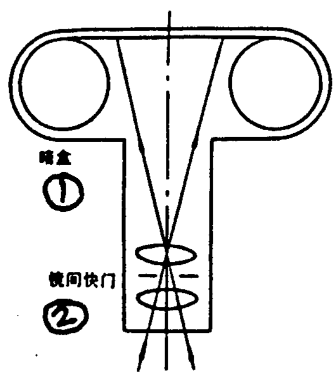


Fig.3 Diagram of Operating Principles Associated with Picture Frame Type Survey Measurement Cameras
Key: (1) Magazine Cassette (2) Shutter Between Lenses

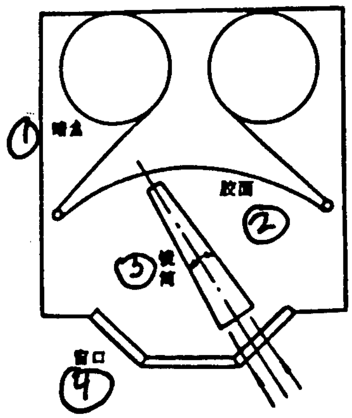


Fig.4 Diagram of Operating Principles Associated with Nodal Point Type Panoramic Cameras

Key: (1) Magazine Cassette (2) Film Surface (3) Focusing Tube (4) Window

Satellite borne star cameras not only must photograph stars with high magnitudes and small intensities of illumination. They, moreover, must take photos synchronously with surface feature cameras. In addition, they operate in environments associated with such strong mixed lights as those coming from the sun, the moon, earth atmosphere reflectance, and so on. These all add difficulty to development work. As a result, it is necessary to meticulously select light exposure times, relative lens apertures, and it is particularly necessary to adopt effective combined measures to guard against and eliminate light noise. If the capabilities of star cameras to prevent and eliminate mixed light are not strong, star images will be submerged in mixed background light. On film, stars with the required threshold values will then not show up.

The star photographing capabilities of satellite borne star cameras developed in China have already been improved from the initial ability to survey only magnitude 4 stars to the display of magnitude 8 stars in 1988, the full presentation of magnitude 7 stars, and the ability to measure magnitude 6 stars. Compared with this, the star cameras on lunar detection devices launched during the U.S. Apollo moon landing program were capable of photographing stars of magnitude 6. The star cameras on the former Soviet Union's Union TM-6 spacecraft are capable of photographing stars of magnitude 5. This clearly shows that Chinese astronavigational star cameras have already entered into advanced world ranks.

APPLICATIONS AND EVALUATIONS OF SYSTEM RESULTS

Progress associated with China's astronavigational visible light remote sensing technologies caused China's satellite general survey systems to take the lead in the early 1980's and enter into application phases. In conjunction with this, in the early 1990's, they began to step over into the second generation. By 1992, the number of photographs associated with 14 returnable type remote sensing satellites was film of observations of the earth from satellites which was several tens of thousands of meters long. After going through processing, interpretation, and explanation by national economic, military, and scientific research departments, a good number of earth remote sensing data which are impossible or difficult to get by other means were obtained, supplying a scientific basis for the drafting up of national economic long term development plans and the carrying out of macro economic policy making, playing an important role in strengthening national defense construction. In conjunction with this, traditional work methods as well as operational modalities were altered in a great many areas, saving large amounts of personnel strength, materiel, and expense. As a result, clear technological, economic, and military benefits were produced. This remote sensing information is already widely used in mineral and petroleum prospecting, earthquake geological analysis, coastal island surveys, harbor and waterway construction, the selection of railroad and highway lines, selection of sites for large scale engineering, topographical map making, archeology of historical remains, current status of fields and forests, water conservancey resources, investigations associated with such things as soil utilization as well as the area of national territory, along with such realms as municipal projects as well as environmental protection, and so on.

The outstanding achievements obtained by China's astronavigational visible light photographic systems have received a high degree of serious attention from the Party and the nation. Chairman Mao Zedong was very happy with and examined in unusual detail the photographs taken during the first flight when returnable type remote sensing satellites entered into orbit. In March 1977, Deputy Chairman Ye Jianying, when checking and approving the photographic results of the second iteration of returnable type remote sensing satellites, submited a memorandum on the spot in association with "returnable type satellites having rendered great service". In December 1990, General Secretary Jiang Zemin inspected second generation astronavigational visible light cameras.

CONCLUSIONS

Chinese astronavigational visible light photographic systems have made long strides in the past 27 years. From here on, development will be toward such areas as improving surface resolution, realizing long life, realizing real time transmission, and so on--causing them to reach an even higher level.

CHARACTERISTICS OF SATELLITE SYNTHETIC APERTURE IMAGING RADAR AND ITS APPLICATIONS IN MILITARY RECONNAISSANCE

Zhang Wanzeng

Translation of "Wei Xing He Cheng Kong Jing Cheng Xiang Lei Da De Te Dian Ji Qi Zai Jun Shi Zhen Cha Zhong De Ying Yong"; Aerospace China, No.11, Nov 93, pp 20-22

I. INTRODUCTION

Since the 1980's, following along with the development of modern science and technology, another strong force in astronavigational reconnaissance and remote sensing equipment--synthetic aperture radar (SAR) imagery--has come to the fore. Once it appeared, it then won people's serious attention and favor for its special strengths and advantages. In the last few years, it has achieved long strides in its development.

In such realms as astronavigational military reconnaissance, as well as remote sensing of the earth's natural resources, and so on, synthetic aperture imagery radar possesses broad applications and huge potential capabilities. As far as its introduction to the world and applications are concerned, it is a large breakthrough and leap forward in remote sensing technology--in particular, astronavigational remote sensing technology. At the present time, test manufacture and development of space based synthetic aperture imagery radar has already and is in the midst of becoming an objective which is pursued in the competition between various astronavigational great powers--astronavigational military great powers in particular.

II. CHARACTERISTICS AND ADVANTAGES

Research and practical actualizations clearly show that, comparing synthetic aperture imaging radar with traditional survey means and reconnaissance remote sensing equipment, it has outstanding characteristics and advantages. Summarizing, they are primarily as follows.

1. Capable of All Weather, All Climate Operations

As far as imagery remote sensing systems such as optical photography, photoelectric imagery, as well as television pictures, and so on, are concerned, they are very greatly subject to the limitations and influences associated with weather and climate. In particular, speaking with regard to distances from the earth of several hundred kilometers even up to a thousand kilometers--due to only being able to operate in the day time--the effective operating time periods in orbit still do not reach 50% of orbital time. In addition to that, they are subject to influences associated with climatic conditions and visibility. In respect to photographic information associated with possible resources that could be made use of--taken within effective operating periods--it is still not enough to actually photograph 70%. As a result, not only is orbital operating time and large amounts of carried information wasted. It is, moreover, difficult to acquire continuous intelligence with regard to military activities as needed--very, very greatly lowering cost benefit ratios of what goes into and is produced by systems as well as economic benefits. Synthetic aperture imagery radar overcomes the fetters of weather conditions. Different from traditional imaging means, it is not subject to the influences and limitations of overcast, rain, fog, and haze. It is able to "penetrate clouds and pull back the fog"--operating day or night.

2. Image Resolution and Distance Are Not Related. Able to Achieve Ideal Imagery Resolutions.

As far as image resolutions are concerned, they are one of the most important technological indices characterizing astronavigational military imagery reconnaissance systems. Due to the fact that military imagery reconnaissance systems use image information capturing military targets, military installations, and the geometrical forms of various types of weapons as primary characteristics, resolutions are, therefore, always the most important technical index sought after in military imagery reconnaissance systems. Traditional optical systems must improve image resolutions. Generally, it is only possible to go through elongating optical system focal lengths or lowering spacecraft flight altitudes as ways of realizing this. However, utilization rates of this type of system per se or

astronavigational platforms must then be lowered very greatly. Because of this, synthetic aperture imaging radar uses the principle of astronavigational reconnaissance platform flight movements taking real radar antennas and forming them into large model antenna arrays in order to form imagery and to operate. As a result, it is possible to acquire good directional resolution imagery. Resolutions in distance and direction are also capable of going through pulse compression methods to achieve a certain improvement.

Synthetic aperture imaging radar is capable of using multiple types of polarization methods to operate. On the basis of requirements, radar systems send out electromagnetic waves with different polarization methods to carry out reconnaissance and survey with regard to specially designated areas and specially designated targets. It is then possible to acquire image informataion which is advantageous to interpretation and analysis. Use is made of strong echo characteristics associated with electromagnetic waves sent out by synthetic aperture imaging radar against target forms possessing angular reflectors. Selecting the angle of incidence of radar beams appropriately, it is also possible to improve resolution capabilities with regard to target images. With respect to images captured by synthetic aperture imagery radars, if use is made of different handling methods to implement computer processing, it is also possible to obtain the target images associated with the different resolutions required.

3. Possesses Certain Penetration Capabilities as Well as Display Capabilities with Regard to Moving Targets

In respect to electromagnetic waves sent out by synthetic aperture imaging radars, they possess certain penetrating and reflecting capabilties in regard to water surfaces, layers of ice, accumulated snow, and loose, dry, sandy soils. This characteristic of applied systems makes it possible to carry out reconnaissance surveys and camoflage exposure with regard to underwater targets and military installations partially hidden under the earth. In July 1987, the former Soviet Union launched the Almaz experimental model earth resources satellite. In imagery that it took of the bottom of the sea in Piji (phonetic) Sound in the U.S. state of Washington it was possible to clearly resolve the status of undulations in land forms at the bottom of the sea at depths of 174-267 meters. The Almaz satellite also discovered and surveyed petroleum transport pipelines laid underground.

Due to the fact that synthetic aperture imaging radar uses operational methods associated with actively transmited electromagnetic waves and receiving electromagnetic echoes reflected back from targets, it, therefore, has certain display capabilities with regard to moving targets. It is capable of being used in reconnaissance, monitoring, and tracking associated with moving military targets and military maneuvers. Speaking in

terms of military reconnaissance, this is critically important. It is yet another leap for remote sensing imagery. /21

4. Possesses Certain Side Look, Quantitative Survey, and Real Time Data Processing Capabilities

In order for optical photography and television shooting to improve image resolutions, option is generally made for the use of long focal length optical systems. As a result, fields of view are narrow. Surface coverage ranges are small. Synthetic aperture imagery radar possesses side look survey capabilites. It is, therefore, possible to survey and cover regions and targets several hundred kilometers on the two sides of the flight orbit. The systems in question are also capable, through calibration of acquired radar images, of obtaining quantitative information associated with targets. This makes a conversion from qualitative analysis to quantitative analysis with regard to monitoring stationary targets, tracking moving targets, and realizing military reconnaissance intelligence, as well as a conversion to intelligence and automatization for information processing provide the key conditions. Besides this, synthetic aperture imaging radar also possesses transmission to the surface of reconnaissance information in orbit in real time or close to real time going through data relay satellites. In this way, not only is data transmission pressure between satellites and earth reduced. The timeliness of intelligence is also improved. Table 1 is a comparison of satellite radar imaging and optical photographic remote sensing characteristics.

In the same way as other remote sensing equipment, synthetic aperture imaging radar also has definite weak points and limitations. These are primarily that the images obtained have relatively large geometrical distortions; that image restoration requires going through processing procedures that are relatively numerous and diverse, and that, after restoration, images have faculae static; that image interpretation and explanation is complicated and difficult compared to optical photography; that system power consumption is large, and so forth.

III. DEVELOPMENT STATUS AND APPLICATIONS IN MILITARY RECONNAISSANCE

At the end of the 1950's and in the early 1960's, following along with the development of modern sciences and technologies such as radar technology, electronics technology, computer technology, as well as information transmission technology, and so on, synthetic aperture imaging radar applications were born (see Table 2). On 16 July, 1969, synthetic aperture imaging radar carried out its maiden flight on the U.S. launched Apollo

11 moon landing space ship. In the first iteration, the feasibility and potential of its application in astronavigational reconnaissance were demonstrated. At that time, at altitudes 15km above the moon, it respectively acquired image data with different surface resolutions of 10 meters, 100 meters, and 300 meters on the lunar surface. In conjunction with this, it was capable of penetrating the lunar surface to depths of 160-1300 meters. In June of 1978, on the U.S. launched Seasat-1,

Table 1 Comparision of Satellite Radar Imaging and Optical Photographic Remote Sensing Device Performance

Item	Radar Imaging	Optical Photography
Resolution	Slightly Poor. Not Related to Orbital Altitude. Little Noise or Interference.	High. Drops as function of Increases in Orbital Altitude.
Survey Capabilities	Capable of Carrying Out Large Scope Surveys of the Earth's Surface, Underground, the Surface of Water, Underwater, and in the Air.	Only Able to Carry Out Surveys of the Earth's Surface.
	Possesses Relatively Large Side Look Capabilities.	Limited Side Look Capabilities.
	Appropriate for Use in Surveys of Various Types of Military Targets.	Only Able to Carry Out Surveys of Targets Exposed on the Earth's Surface.
	Has Capabilities for Carrying Out Surveys of Maneuvering Targets and Exposing Camoflage.	
Information Transmission Method	Real Time	After the Fact.
Capabilites to Adapt to Weather and Climate	All Weather. All Climate.	Under Day Light Conditions with Good Visibility.
Timeliness	Good.	Poor.

Operating Life	Long. Can Reach Several Years.	Comparatively Short. Limited by Amounts of Film.

synthetic aperture imaging radar was also applied. The terrestrial surface coverage widths were 232km. Surface resolutions were 23m. CCD signal processors on board the satellite were capable, in a real time manner, of taking radar data and restoring it into imagery information. After the U.S. space shuttle was launched successfully in April 1984, synthetic aperture imaging radar tests were carried out again in succession on Columbia and Challenger, obtaining results attracting the attention of the world--for instance, imagery data associated with ancient water courses of the Nile River. On 2 December 1988, the U.S. launched the Atlantis space shuttle, which carried, and, in conjunction with that, released in orbit, a radar military reconnaissance satellite named Lacrosse. According to reports, synthetic aperture imaging radar on board the satellite is capable of surveying "military activities on 80% of the territory of the former Soviet Union and Eastern Europe", "reconnoitering on the surface objects the size of a person", and is also capable of "checking on the status of the former Soviet Union's compliance with pacts limiting strategic weapons". Besides the U.S., organizations of the former Soviet Union, the European space agency, Japan, as well as Canada, and other nations have recently also all been competing to test manufacture and develop various synthetic aperture imaging radar satellite systems. The former Soviet Union and the current Russia, one after the other, launched, in July 1987 and March 1991, the Almaz experimental model with main remote sensing equipment of synthetic aperture imaging radar as well as applied models of earth natural resource satellites. The surface resolution associated with the satellite model for practical use has already reached 15-30 meters. Following after the former Soviet Union, the European space agency also launched, on 17 July 1991, the earth resources satellite ERS-1. In the area of developing radar imaging technology, Japan relied on their advanced technology and equipment and roused herself to catch up to them. Following after the European space agency, on 11 February 1992, Japan successfully launched the JERS-1 radar imaging research satellite with surface resolutions of 18x18 meters.

Table 2 Comparison of Satellite Radar Imagery Remote Sensing Device Characteristics

Satellite Nomenclature	Launch Date (Day.Mo.Yr)	Resolution (Meters)	Observation Band Width (Kilometers)	Repeat Observation Period

				(Days)
Seasat-1	1978.6	23	232	
Lacrosse	1988.12.2	1		
Almaz-2	1991.3.31	15	200-350	
ERS-1	1991.7.17	20		3
JERS-1	1992.2.11	18	75	
Radar Satellite	1994 (planned)	10		3

/22

Canada's radar imagery earth resources satellite, Radarsat, which has a surface resolution of 15 meters, is planned to be launched aloft in 1994.

Satellite synthetic aperture imaging radar has huge application potential in astronavigational military reconnaissance as well as extensive prospects for development. As far as its applications in military affairs are concerned--summarizing--they are primarily in the areas below:

1. reconnaissance and surveillance;
2. reconnaissance and survey of targets concealed underground, underwater, and in camoflage;
3. reconnaissance, tracking, and surveillance associated with maneuvering military targets as well as battlefield situations and the progress of wars; and,
4. the making of military terrain maps.

In the area of civilian uses, it is capable of broad utilization in earth natural resource surveys such as oceans, geology, hydrology, agricultural land and forests, metrology, and so on, as well as monitoring the environment.

IV. CONCLUSIONS

To summarize what was said above--with regard to the characteristics and superiorities of synthetic aperture imaging radar and its applications in the realms of military reconnaissance and earth resource remote sensing--practical realization of tests and verifications have already been achieved. The prophecy put forward by a number of western astronavigational and remote sensing specialists that "satellite synthetic aperture imaging radar systems will come to dominate the 1990's and the beginning of the 21st century" is not unreasonable.

SOUTH AFRICAN GLOBAL IMAGING SATELLITE SYSTEM

Chen Wen

Translation of "Nan Fei De Di Qiu Cheng Xiang Wei Xing Xi Tong"; Aerospace China, No.11, Nov 1993, p 22

South Africa is in the midst of developing a satellite called the Green Star. It is a low earth orbit imaging satellite with a price of 60 million U.S. dollars, thereby causing the country in question to have hopes of becoming one of the pioneers in commercial remote sensing systems.

Detailed engineering models of the Green Star were displayed at the 40th Paris Air Show, giving rise to extremely great interest. The satellite in question will be launched before 1995.

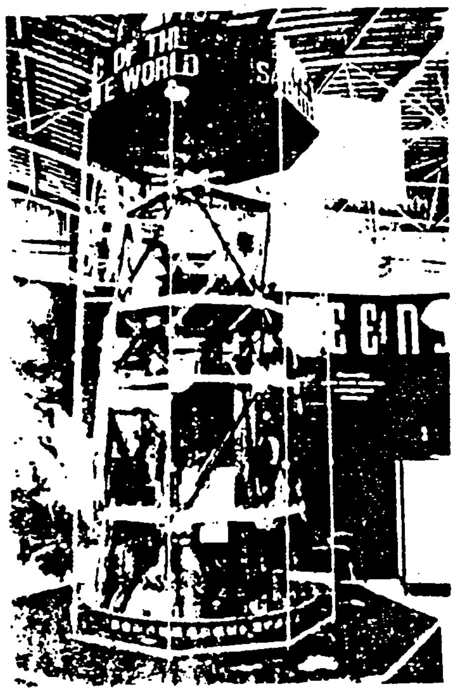
The satellite primarily acts in commercial applications. However, it is also capable of supplying basic space reconnaissance intelligence for South Africa or Israel--users of that kind. However, Israel will not take part in the project in question.

The project in question is one part of a program to implement the development of a complete set of space foundations that are fully independent. This project includes developing a type of 72 ton class solid carrier rocket as well as the establishment on the southern tip of Africa of a set of modernized, comprehensive launch facilities.

The Green Star weighs 300kg. It uses graphite polyethylene structural members. It makes use of titanium for propellant storage tanks. The thrusters are comparatively advanced. These are all autonomously developed by South Africa. Other components will be procured from foreign companies. For example, the satellite driving wheel will be supplied by the British Aerospace company.

This satellite will carry two sets of South African imaging systems. It operates in orbits at an altitude of 400km. The resolution of the cone shaped panchromatic imaging systems is 2.5 meters. The systems in question will be assisted by the use of Doppler cameras with resolutions of 16 meters. Cameras are most appropriate to operations in two spectral bands associated with agricultural data. At the present time, the carrier rocket launching this satellite has still not been determined. As a result, a search for a cooperative partner is under way in Europe.

Market investigations have currently already been carried out with regard to agriculture, soil utilization, mineral/petroleum geology, as well as other possible users in order to facilitate the support of this project.



South Africa's Green Star Engineering Model

Besides this satellite, South Africa is also in the process of developing a type of three stage solid carrier rocket called RSA-4. This type of rocket is 28 meters long and will be capable of sending a 515 kilogram useful load into low earth orbit.

U.S. ANALYZES PROBLEMS ASSOCIATED WITH LOW HIT PERCENTAGES FOR THE TOMAHAWK MISSILE

Hua Hongxun Zhu Linqi (Trans.)
Jiang Yuping (Ed.)

Translation of "Mei Guo Fen Xi Zhan Fu Dao Dan Ming Zhong Lyu Di De Wen Ti"; Aerospace China, No.11, Nov 1993, p 35

Despite the fact that, recently, improvements were carried out on aiming systems associated with Tomahawk missiles, during air raids on Baghdad on 26 June of this year, however, only 67% of missiles hit their targets. The U.S. Defense Department suspects that this was caused by Tomahawk missile flight control and navigation systems developing malfunctions and to being hit by Iraqi force air defense fire. At the present time, analytical research is in the midst of being carried out in this area.

On 26 June of this year, two U.S. Navy warships launched 24 Tomahawk missiles at a building complex associated with the central intelligence agency headquaters set up in Iraq. 16 missiles among these hit their aiming points. 3 missiles hit other areas of the building. It is not clear where 1 missile went. 3 missiles fell into inhabited areas in the vicinity. A final missile was never launched because the navigation system developed malfunctions. Although a 67% hit percentage is passable, it is, however, still far, far lower than the combat successes of Tomahawk missiles in the past.

During an air raid on 17 January of this year against an Iraqi nuclear processing facility, a total of 54 Tomahawk missiles were launched . Hit percentages reached the anticipated 80%-85%. In this air raid, there were 7 Tomahawk missiles that fell in areas in the vicinity of targets or fell in open areas. However, they did not hit targets. U.S. Navy preliminary analysis acknowledges that the cause producing attack faults may possibly be that aiming data loaded before launch had tiny measurement errors. This caused missiles to carry out mistaken guidance corrections in the last few seconds before detonation. Analysis results clearly show that the appearance of aiming errors and standardization of the positions of aiming points by users on target area imagery are related processes. This process is not capable of being interfered with at all. Even if it is very small jolts, it will still produce standardization errors. In order to eliminate the errors which may be brought in for this reason, during the 26 June attack, Tomahawk missiles opted for the use of a type of new digital flight program system. However, hit percentages were still only 67%.

During the raid carried out on 26 June, all Tomahawk missiles that missed targets exploded within areas a few hundred

meters from targets. During flight processes, Tomahawk missiles carried out corrections with regard to the positions they were at through "digital scenery matching area correlators" (DS-MAC) on board the missiles. DSMAC systems are capable, before the 480kg warheads open their safeties, of making missiles carry out comparisons of the scenery associated with certain specially designated places in the vicinity of targets and imagery loaded in the missile. However, when these missiles approach targets and, in conjunction with that, carry out final pitching maneuvers, problems showed up. Going through analysis, the possibility that it was due to dust or bad weather conditions leading to malfunctions was eliminated.

There are conjectures that believe--during the 26 June raid--that part of the Tomahawk missiles not hitting targets was possibly due to flight control mechanisms giving rise to malfunctions, causing missiles to deviate from course directions and not align on targets. Another cause may possibly have been that it was due to intense Iraqi air defense artillery. This is because the numbers of Tomahawk missiles equiped with global positioning system (GPS) guidance systems was limited. Therefore, when drawing up battle plans, it was still not possible to opt for the use of multiple direction offensive methods. In this way, Iraqi air defense artillery was then allowed an opportunity to carry out intercepts of Tomahawk missiles.

GENERAL SURVEY OF MANNED SPACE ACTIVITIES BY THE FORMER SOVIET UNION (II)

Wang Jinhua

Translation of "Qian Su Lian Zai Ren Hang Tian Huo Dong Yi Lan (II)"; Aerospace China, No.11, Nov 1993, pp 36-37

Union No.12 Manned Spacecraft

Flight dates 27-29 September 1973

Crew Lazaliefu (phonetic) (commander), Makaluofu (phonetic) (engineer on board)

Flight missions Test flight craft systems after improvements. During flight craft maneuver flight, direction finding, and stable operation, practiced operational processes under various types of flight configurations. Besides this, also did spectrum photography of natural products; recorded crew physiological indices.

Union No.13 Manned Spacecraft

Flight dates 18-26 December 1973

Crew Kelijike (phonetic) (commander), Liebiejiefu (phonetic) (engineer on board)

Flight missions Continued to carry out comprehensive tests with regard to various spacecraft systems. Observed ultraviolet spectra of different constellations using astronomical telescopes. Carried out spectral photography of certain sections of the earth's surface. Studied different adaptation phases of blood circulation characteristics and other physiological alterations associated with crew members' cerebra.

Salute Gun No.3 Space Station

Launch Date 25 June 1974

Flight missions It was a comprehensive military-civilian use space station. The attitude control systems were comparatively greatly improved.

Union No.14 Manned Spacecraft

Flight dates 3-19 July 1974

Crew Boboweiqi (phonetic) (commander), Aerqiuxi (phonetic) (engineer on board)

Flight missions Docked with Salute Gun No.3 space station. Crew entered station and worked for 15 days. Besides carrying out checks with regard to attitude control systems as well as structures following improvements and carrying out tests on maneuver motions and berthing procedures in various types of configurations, they also carried out extensive observations and studies in regard to various areas such as surface targets (including military targets), cosmic physics processes (including characteristics of the cosmos, γ rays, analysis of star spectra, recording of charged particles, and research with respect to meteor material), medico-physiology (including observations of the state of health of crew members and research with regard to influences on the various organs of the human body of long term space flight as well as characteristics of biological activities), and drew up rational crew systems of work and rest.

Union No.15 Manned Spacecraft

Flight dates 26-28 August 1974

Crew Salafanofu (phonetic) (commander), Deming (phonetic) (engineer on board)

Flight missions To dock and fly with Salute Gun No.3 space station. However, multiple iterations of berthing and docking were all announced as failures. Later, there was emergency return of the spacecraft, landing at night.

Union No.16 Manned Spacecraft

Flight dates 2-8 December 1974

Crew Feilipuqinke (phonetic) (commander), Dukeweishennikefu (phonetic) (on board engineer)

Flight missions Main flight mission was to prepare for joint Soviet-U.S. flight in 1975, carrying out tests with regard to a number of new designs and improvements for this joint flight. At the same time as this, observation and photography were also carried out on certain areas of the earth's surface, and a number of medical studies were completed.

Salute Gun No.4 Space Station

Launch date 26 December 1974

Flight missions Docking flights with Union manned spacecraft and the carrying out of long term observation work and extensive research, which crew were able to do in the station.

Union No.17 Manned Spacecraft

Flight dates 11 Jan - 9 Feb 1975

Crew Gubaliefu (phonetic) (commander), Gelieqike (phonetic) (on board engineer)

Flight missions Docking flight with Salute Gun No.4 space station. The crew crossed over into the space station and worked for 29 and a half days. Scientific experiments and research included studying space physics processes and physical phenomena, observing the geology of the surface of the earth, carrying out medical and physiological experiments, and testing space station structures as well as systems and equipment on the station after improvements.

Union No.18-1 Manned Spacecraft

Flight date 5 April 1975

Crew Lazaliefu (phonetic) (commander), Makaluofu (phonetic) (on board engineer)

Flight missions Docking flight with Salute Gun No.4 space station. To carry out astronavigational observation work for a period of 40 days. During launch processes, because of rocket deviations, it was not able to enter orbit. It escaped from the rocket and made an emergency return. Lasted 22 minutes.

Union No.18 Manned Spacecraft

Flight dates 24 May - 26 July 1975

Crew Kelijike (commander), Xiewasijiyangnofu (on board engineer)

Flight missions Docking flight with Salute Gun No.4 space station. Crew entered station, living and working for 63 days. Among observations and research completed by the crew were inlcuded carrying out test measurements on spacecraft life support systems, research on the sun, planets, and fixed stars, geological formations associated with the surface of the earth, as well as physical processes associated with the atmosphere and space. Carried out medical and physiological experiments such as observing blood circulation function in static conditions after sleep, measured cardio-pulmonary function under physical strength loads, studied pysiological reactions to the effects of long term weightlessness, as well as preventive measures (including physical training methods), and so on.

Union No.19 Manned Spacecraft

Flight dates 15-21 July 1975

Crew Lieaonofu (phonetic) (commander), Kubasuofu (phonetic) (on board engineer)

Flight missions Carried out docking connection with U.S. Apollo spacecraft. Tested docking systems of the two spacecraft for mutual fit. Recipriocal visits were carried out between the crew members of the two sides. The two spacecraft flew docked together for 2 days. A total of 35 scientific experiments were completed. Among these, 5 were combined experiments. They were man made eclipse tests, ultraviolet ray radiation absorption tests, multiple use smelting furnace tests, influences of radiation and weightlessness factors on fungus cultures, collection of microorganisms on bodies and inside compartments by cotton wipes used mutually by crew members, studying crew member immunity to microorganisms, and so on.

Salute Gun No.5 Space Station

Launch date 22 June 1976

Flight missions It was a space station primarily used for military purposes. It flew docked with the Union 21 and 24 manned spacecraft in succession.

Union No.21 Manned Spacecraft

Flight dates 6 July - 24 August 1976

Crew Woleinofu (phonetic) (commander), Ruoluobaofu (phonetic) (on board engineer) /37

Flight missions After docking with the Salute Gun No.5 space station, crew entered the station and operated for 48 days.

Large amounts of comprehensive research were carried out. In this were included photography of the earth's surface as well as experiments associated with areas of space technology, medical examinations, and so on. During the flight, the crew gave rise to severe psychological illness.

Union No.22 Manned Spacecraft

Flight dates 15-23 September 1976

Crew Beikefusiji (phonetic) (commander), Akesennofu (phonetic) (on board engineer)

Flight missions Examined and improved methods associated with studying the geology of the earth's surface and geographical characteristics from space. At the same time that use was made of multiple sprectrum photographic devices, the earth's surface was photographed in 6 different wave lengths, carrying out earth resources scientific research.

Union No.23 Manned Spacecraft

Flight dates 14-16 October 1976

Crew Zuodaofu (phonetic) (commander), Luoerjiesitewensiji (phonetic) (on board engineer)

Flight missions Originally planned to dock with Salute Gun No.5 space station. However, because docking control systems developed malfunctions, docking failed. The flight was discontinued. On the return trip, it also met with a windstorm, creating an unanticipated splash down on water.

Union No.24 Manned Spacecraft

Flight dates 7-25 February 1977

Crew Geerbateke (phonetic) (commander), Gelazikefu (phonetic) (on board engineer)

Flight missions Continued to carry out a number of experiments and studies begun by the team of Union No.21 . Extensive, in depth medical research was carried out including a series of function tests and measurements implemented quantitatively for physical strength load states in resting conditions as well as on comprehensive exercise units. Option was made for the use of negative pressure systems to simulate the effects of gravity, doing research on the state of the cardiovascular system. Measurements were made under weightless

conditions of vestibular system sensitivities to electrical stimulation effects, and so on.

Salute Gun No.6 Space Station

Launch date 29 September 1977

Flight missions Salute Gun No.6 was the former Soviet Union's second generation space station. Its primary characteristics were docking systems on both the front and back. It was capable of docking two spacecraft at the same time. In conjunction with this, it was fitted with an automatic navigation system. The Salute Gun No.6 acted as an orbital base. Union and Union-T spacecraft frequently carried crew members to the station to work. Progress transport spacecraft then carried expendable supplies and materiel to the space station at fixed intervals. Multiple spacecraft docking in orbit composed a huge "sausage shaped" orbital complex. This was capable of very, very greatly increasing the scale of the space station, increasing its application value. Salute Gun No.6 space station was primarily for civilian use.

Union No.25 Manned Spacecraft

Flight dates 9-11 October 1977

Crew Kewaliannofu (phonetic) (commander), Liu Ming (on board engineer)

Flight missions Originally planned to dock with Salute Gun No.6. However, due to the development of deviations in docking programs, it was not possible to dock successfully.

Union No.26 Manned Spacecraft

Flight dates 10 December 1977 - 16 January 1978

Crew Lamannianke (phonetic) (commander), Gelieqike (phonetic) (on board engineer)

Flight missions Docked with Salute Gun No.6 space station. Crew entered into station and worked and lived 96 days. During flight processes crew did 88 minutes of extravehicular activities. Primary mission was to verify the capabilities of new, light and convenient types of life support systems as well as "semi hard" types of space suits for use outside vehicles, capabilities to go in and out of space station compartment exits, as well as the feasibility of carrying out activities and maintenance outside of vehicles. The crew came back on Union No.27 spacecraft.

(Continued)

THE FORMER SOVIET UNION'S ASTRONAVIGATIONAL TELEMETRY AND CONTROL SYSTEMS

Zhang Yinlong

Translation of "Qian Su Lian Hang Tian Ce Kong Xi Tong"; Aerospace China, No.11, Nov 1993, pp 43-46

The former Soviet Union's astronavigational telemetry and control system includes two flight control centers, approximately 15 telemetry and control stations, 6 survey ships, and 2 relay satellites. This article introduces, respectively, the basic structures and primary functions of flight control centers, telemetry and control stations, survey ships, and relay satellites.

I. INTRODUCTION

In order to provide launch support and implement operational management with regard to spacecraft of various types, the former Soviet Union went through over 30 years of construction, renovation, and expansion--possessing an astronavigational telemetry and control system which was huge and fully functioned.

This astronavigational telemetry and control system served as subjects the Soviet Union's satellites, spacecraft, space stations, and space shuttles. The telemetry and control system was capable of providing good telemetry and control support in all cases for the launch and orbit entry phase, orbital operation phase (including rendezvous and docking), and reentry and return

phase of these spacecraft. The primary missions of the telemetry and control system were as follows:

---to carry out measurements with regard to spacecraft, accurately determining their orbital parameters;

---to provide necessary surface support with respect to spacecraft space guidance systems and autonomous flight systems;

---to receive and process spacecraft telemetry information;

---to carry out operational configuration control and dynamic control in regard to spacecraft;

---to receive television information from manned spacecraft, completing communication with crew members;

---to guarantee emergency lifesaving for crew members;

---to carry out information exchange or communications with application departments, development departments, crew training centers, government departments, and news units.

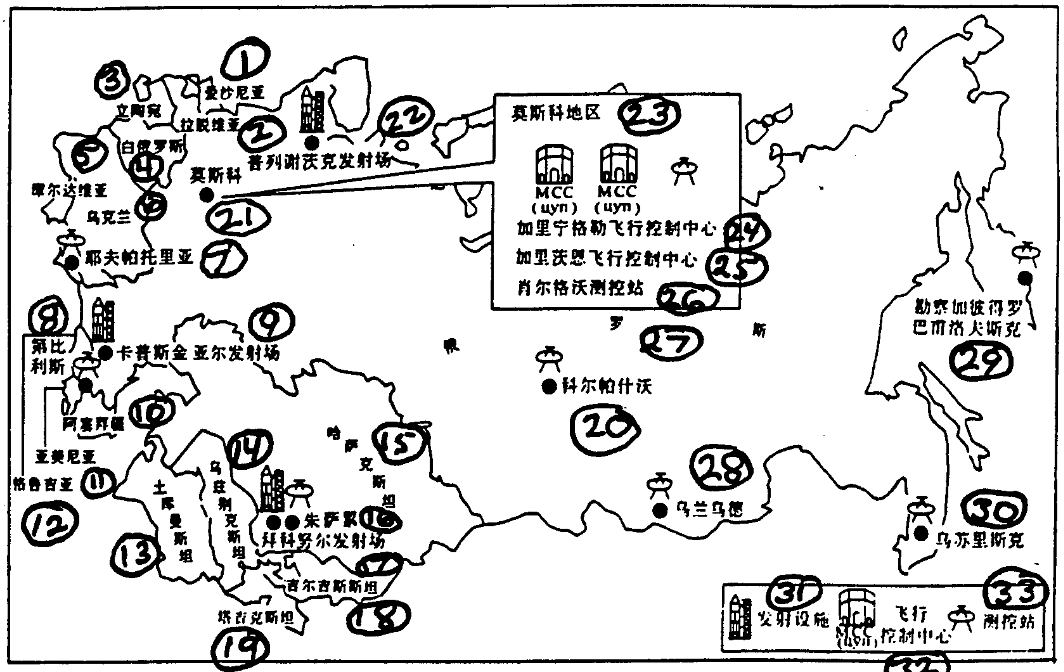


Fig.1 The Former Soviet Union's Main Launching Sites, Flight Control Centers, and Telemetry and Control Stations

Key: (1) Estonia (2) Latvia (3) Lithuania (4) Byelorus (5) Moldavia (6) Ukraine (7) Yefupatuoliya (phonetic) (8) Tiblisi (9) Kapusijinyaer (phonetic) Launching Site (10) Azerbaijan (11) Armenia (12) Georgia (13) Turkmanistan (14) Uzbekistan (15) Khazakstan (16) Zhusalei (phonetic) (17) Baikanur Launching Site (18) Kirghizstan (19) Tazhikistan (20) Keerpashenwo (phonetic) (21) Moscow (22) Puliexiecike (phonetic) Launching Site (23) Moscow Region (24) Jialininggele (phonetic) Flight Control Center (25) Jialicien (phonetic) Flight Control Center (26) Xiaoergewo (phonetic) Telemetry and Control Station (27) Russia (28) Wulanwude (phonetic) (29) Kamchatska Petropavlovsk (30) Wusulisike (phonetic) (31) Launch Equipment (32) Flight Control Center (33) Telemetry and Control Center /44

Telemetry and control systems are composed of flight control centers, telemetry and control stations, survey ships, and relay satellites. Flight control centers and primary telemetry and control stations are as shown in Fig.1. Besides a small number of departments subordinate to the Russian Federation

astronavigational bureau, this telemetry and control system is, for the most part, subordinate to astronavigational units.

II. FLIGHT CONTROL CENTERS

During astronavigational flight missions, flight control centers are nexses for the implementation of information exchange, data processing, monitoring and control display, and command decision making. The former Soviet Union's most important flight control centers were the Jialininggele (phonetic) flight control center located approximately 15km northeast of Moscow and the Jialicien (phonetic) flight control center located approximately 40km southwest of Moscow. Jialininggele (phonetic) flight control center was abbreviated as

1 (cyrillic) or MCC (English). It was a manned space flight control center subordinate to the astronavigational bureau. Jialicien (phonetic) flight control center provided support for various types of spacecraft (including manned spacecraft and satellites). It was subordinate to astronavigational units. It was also called the general center for astronavigational unit tests. Below we introduce the Jialininggele (phonetic) flight control center.

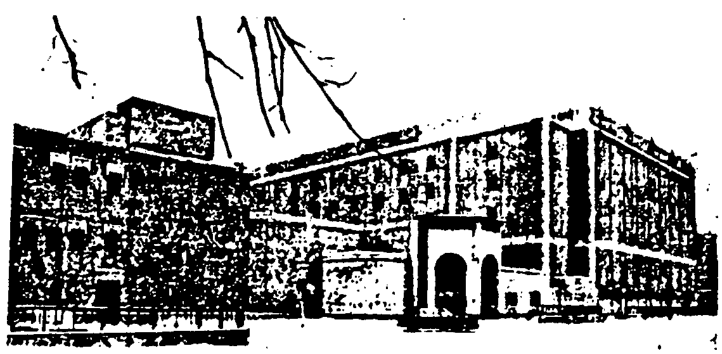


Fig.2 Jialininggele (Phonetic) Flight Control Center Main Building

The predecessor of the Jialininggele (phonetic) flight control center was a coordination computing center. The flight control center was built in 1973 and already has over 30 years of history. The constuction area of the center in question is approximately 66800 square meters. The main building is as shown in Fig.2. There were over 2400 hundred operating personnel. Among these were included the most outstanding Soviet experts in such fields as ballistics (orbits), space navigation, telemetry, return and reentry, and so on. The current chief is V. Luobaqiaofu (Phonetic). The main missions of the flight center in question are: to accomplish flight control for manned spacecraft (including manned spaceships, transport spacechips, space stations, space shuttles, and so on), to accomplish flight control associated with deep space survey craft, and to make real developments in scientific research. The center in question is set up in 12 types of specialties--for example, ballistic (orbital) surety, telemetry surety, command and control, display, communications, and so forth. This center operates in a multiple objective configuration. Using the Peace space station complex as an example, this combination includes the main Peace compartment, the Quantum compartment, the Crystal compartment, Progress space ships, and Union spacecraft. At a maximum, it is capable of reaching 7 compartments combined together and moving in orbit. The flight control center is capable of carrying out communications and telemetry and control with regard to these 7 modules at the same time. The center in question possesses very high technical levels and abundant experience in guaranteeing orbital movements, rendezvous and docking, as well as reentry and return aspects associated with spacecraft.

Jialininggele (phonetic) flight control center has two command halls--the Peace space station command hall and the Snowstorm space shuttle command hall. There are two small halls on the two sides of each command hall. The small halls on the two sides of the Peace space station command hall are, respectively, the Union manned spacecraft command hall and the Progress transport space ship command hall. The small halls on the two sides of the Snowstorm space shutlle command hall are used in command and control of deep space survey craft. The layouts of the two halls and the placement of equipment are basically in line with each other.

The Peace command hall was constructed in 1976. The hall is divided into two levels. The main equipment on one level is monitoring, control, and display units as well as large screens. Monitoring, control, and display units are divided into 5 rows with a total of 24 sections. Each section is 2 to 3 monitoring, control, and display units (cathode ray tube displays and keyboards). The front of the hall is 5 screens. A large one is in the middle with dimensions of 8 meters x 6 meters. It primarily displays spacecraft flight orbits on the background of

a world map. 4 screens placed on the two sides have their own dimensions of 4 meters x 3 meters, respectively displaying spacecraft imagery, television pictures of crew working life, orbital schematics, telemetry and control plans, text descriptions of key incidents, and so on. The display contents associated with each screen are capable of being switched over as needed. The first hall level is primarily operating personnel, analysis personnel, and dispatch command personnel. The second level of the hall has three rows of seats. They are used to arrange command personnel, outside assistance personnel, and visitors. The back side of the second level is a national committee conference room. There are 21 seats and 6 monitors.

Computer systems are the core of flight control centers. These systems are composed of multiple types of large scale computers. Each computer is also composed of multiple processor units (some reach several tens of units). Therefore, overall operational speeds are very high. In accordance with functions, central computers can be divided into ballistic (orbital) surety computers, telemetry processing computers, command and planning formation computers, simulation computers, and so on. Many of these computers opt for the use of medium scale integrated circuits. Storage sections opt for the use of large scale integrated circuits. Cooling methods are water cooling. Flight control center computers are connected into a network. The data transmission rate is 10 megabits/second. Data processing capabilities of the computer systems in question are strong. Real time characteristics are high. Reliability is high. However, computer volume is large. In areas such as systems and standards, there is no compatibility with computers which are commonly used internationally.

In order to guarantee flight control center communications, centers have 720 communications circuits. Among these are included 20 wide band circuits associated with the transmission of television signals. The control centers in question make use of the satellite communications station in the Xiaoergewo station located approximately 35 kilometers east of Moscow. Communications are realized with telemetry and control stations (ships) through Lightning and Horizon communications satellites. At the same time, use is made of terminal stations inside the Xiaoergewo station, carrying out communications with the Beam relay satellite.

III. TELEMETRY AND CONTROL STATIONS

1. Movement Phase Telemetry and Control Stations

In order to improve spacecraft telemetry and control coverage rates, telemetry and control stations were "uniformly placed" in an east-west direction in the territory of the former Soviet Union. From the Kamchatka Peninsula to the Jialimiya (phonetic) Peninsula, 15 main telemetry and control stations were spread, covering a longitude range of close to 180°. Among these, 7 telemetry and control stations were used in telemetry and control associated with manned space flights. Fig.1 shows the locations of these 7 stations. These 7 stations are: the Petropavlovsk station on the Kamchatka Peninsula (ППК), the Wusulisike (phonetic) station (УСК) located in the vicinity of Vladivostok (Haicanwai), Wulanwude (phonetic) station located south of Lake Baikal (УЛЦ), Keerpashenwo (phonetic) station (КЛП) located north of Novosibirsk, Zhusalei station (ПЖС) located east of the Baikanur launch site, Tiblisi station (ТБЛ) located in the Caucasus, and Yefupatuoliya (phonetic) station (EBT) on the Kelimiya (phonetic) Peninsula. Since 1992, Tiblisi station has not been participating in operations. It is already closed. It is said that Yefupatuoliya (phonetic) station will also be closed. It is planned to replace it with a Rostov station (located where the Volga River enters the sea). No matter whether it is manned space flights or other spacecraft movements, Xiaoergewo (phonetic) station takes charge of onerous telemetry, control, and communications missions in all cases.

2. Drive Phase Telemetry and Control Stations

Besides telemetry and control stations in telemetry and control networks, in order to carry out measurements with regard to drive flight phases associated with lifting rockets carrying spacecraft, the three launch sites shown in Fig.1 (Baikanur launch site, Puliexiecike (phonetic) launch site, and Kapusijinyaer (phonetic) launch site) all must be equiped with telemetry and control stations.

Baikanur launch site is the former Soviet Union's largest launch site. It possesses 5 telemetry and control stations: No.1 survey station located in the vicinity of the Union carrier rocket launch site, the No.2 survey station located in the vicinity of the Zenith carrier rocket launch site, the No.3 survey station located in the vicinity of the Proton carrier

rocket launch site, the No.4 survey station (also called Vega survey station) located in the vicinity of Leninsk (launch site living area, which is a town), and No.5 survey station (also called Saturn survey station). No.1 and No.5 survey stations are large model survey stations fitted with multiple function telemetry and control equipment.

Besides the 5 stations above, east of Baikanur launch site, there are also 4 stations respectively located at Alaersike (phonetic), Kezier-Aoerda (phonetic), Amangede (phonetic), and Aleishagan antimissile target range.

3. Main Equipment of Telemetry and Control Stations

The main equipment of telemetry and control stations has telemetry equipment, remote control equipment, multiple function telemetry and control equipment, and so on. Multiple function telemetry and control equipment is typical telemetry and control equipmment associated with the former Soviet Union. In accordance with the former Soviet Union's introduction of 9 sets of multiple function telemetry and control equipment, 7 sets among them were on land, and 2 sets were on survey ships. Multiple function telemetry and control equipment is multiple carrier wave composite telemetry and control systems. It has multiple types of functions such as simultaneously measuring orbits, telemetry, remote control, communications, as well as television reception, and so on. Operating frequency up links are 760-770MHz. Down links are 920-930MHz. Orbital measurements opt for the use of DD (distance and distance change rate) systems. Telemetry code speed is 256 thousand bits/second. Remote control code speed is 250 bits/second. Distance measurement precision is 10 meters. Distance change rate measurement precision is 1cm/second.

IV. SURVEY SHIPS

In order to improve telemetry coverage rates with regard to spacecraft, the former Soviet Union constructed very large scale maritime survey ship systems. From the early 1970's to the end of the 1980's, use was made of up to 11 survey ships. Most of the survey ships were named in honor of space flight crew members who had sacrificed themselves. In 1989, 5 survey ships were retired. There are currently 6 survey ships. Among these, the Yuri Gagarin and the Academician Sergei Kuroliov (normally, always anchoring in Odessa), are large model, comprehensive survey ships fitted with multiple function telemetry and control equipment as well as other telemetry, control, and communications equipment. The other 4 (normally, always anchoring in St.Petersburg) are telemetry and communications ships. The Yuri Gagarin is 231.6 meters long, 32 meters wide, displaces 45000 tons, draws 8.5 meters, has a power of 1397.45 kilowatts, a speed of 18 knots, a range of 20000 nautical miles, a crew of 136, and 212 personnel for carrying out missions. The Academician Sergei

Kuroliov is 180.8 meters long, 25 meters wide, displaces 21250 tons, draws 7.7 meters, has a power of 882.6 kilowatts, a speed of 17.5 knots, a range of 22500 nautical miles, a crew of 119, and 118 personnel for carrying out missions. 4 telemetry and communications ships fitted with telemetry equipment and communications equipment were remodeled from other ships. They are called, respectively, the Waerkefu (phonetic), the Bieliyayefu (phonetic), the Dubuoluowaersiji (phonetic), and the Pachayefusiji (phonetic). Their scale and performance are the same: 129.9 meters long, 16.7 meters wide, displace 8950 tons, draw 6.6 meters, have powers of 382.5 kilowatts, speeds of 14.7 knots, range of 16000 nautical miles, crews of 66, and 77 personnel to carry out missions. /46

In 1988, the Soviet Union began to build a new model survey ship, the Academician Biliujin (phonetic). Due to such causes as expenses, it has still not been put into service up to now. The ship in question is 164.2 meters long, 24.8 meters wide, displaces 16300 tons, draws 6.7 meters, has a power of 956.2 kilowatts, speed is 18 knots, cruising range is 20000 nautical miles, has a crew of 90, and 120 personnel for carrying out missions. Opting for the use of advanced stabilization technology, ship's roll is under 10°. Option is made for the use of dual rudders. There are lateral propulsion functions. It is possible to turn over an original location. It is planned to be fitted with multiple function telemetry and control equipment as well as other telemetry, control, and communications equipment. The ship is also fitted with equipment used in return compartment search and recovery. The ship in question opts for the use of the global navigation satellite system (Glonass) to carry out navigation.

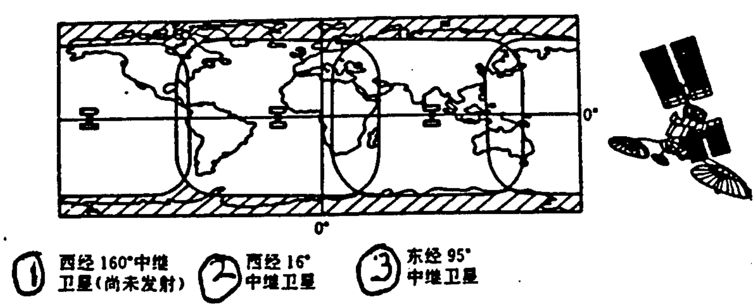


Fig.3 Distribution of Former Soviet Union Relay Satellites and Relay Satellite Exterior Form

Key: (1) West Longitude 160° Relay Satellite (Not Yet Launched) (2) West Longitude 16° Relay Satellite (3) East Longitude 95° Relay Satellite

V. RELAY SATELLITES

The Beam relay satellites which the former Soviet Union was in the midst of using were a total of two. They were respectively positioned at east longitude 95° and west longitude 16°. Telemetry and control coverage rates for spacecraft are capable of reaching 85%. It is planned to place a satellite at 160° west longitude. At that time, coverage rates are capable of reaching 100%. Relay satellite distribution and relay satellite exterior form are as shown in Fig.3. The rectangle shaped boxes in the Fig. stand for relay satellite coverage areas. The two parabolic surface antennas of relay satellites respectively communicate with the surface and the Peace space station. Phase control array antennas between the two parabolic surfaces communicate with spacecraft. Information which terminal stations send to space ships and space stations (coming from flight control stations) contains such things as command communictions, voice, and so on. Information which terminal stations send to flight control centers (coming from space ships and space stations) contains telemetry information, voice, television, and so forth.

Terminal stations placed in Xiaoergewo (phonetic) telemetry and control station have wide band communications circuits with flight control centers. Terminal stations have two auxilliary antennas and two sets of equipment. It is possible to communicate with two relay satellites at the same time. Option is made for the Ku wave band. Up link frequencies are 14.6 gegahertz. Down link frequencies are 10.9 gegahertz. Antenna diameters are 16 meters. Beam widths are: up links approximately 1°, down links approximately 1.2°.

After the establishment of relay satellite systems, advantages such as high coverage rates and convenience of use were fully displayed. In 1992, among the important space flight missions which Russia carried out (including, respectively, the Union TM-14 spacecraft carrying German and French crew members and the Union TM-15 spacecraft , one after the other, rendezvousing and docking with the Peace space station), option was made in all cases for the use of telemetry and control plans associated with ground telemetry and control stations plus relay satellites, but use was not made of survey ships.